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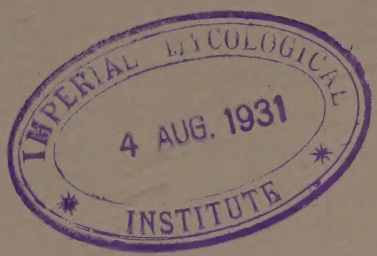
FINAL SUMMARY OF THE WORK ON DISEASES OF LILIES

1930

By
DR. CARL E. F. GUTERMAN

FOR THE LILY DISEASE INVESTIGATION FELLOWSHIP



Reprinted from Horticultural Society of New York
Yearbook, pp. 51-102, January, 1930

DISEASES OF LILIES

By

CARL E. F. GUTERMAN

FOR THE LILY DISEASE INVESTIGATION FELLOWSHIP

The value of lilies, for ornamental purposes, has long been appreciated. In fact, reference to ancient records has revealed their use by the inhabitants of Crete as early as 2500-1500 B.C. In recent years, the popularity of these plants has markedly increased with the result that the propagation and cultivation of lily bulbs now constitutes an industry of considerable importance in numerous countries. The United States, alone, imports each year many thousands of cases of lily bulbs which are grown either in gardens for their ornamental value or in greenhouses for use as cut flowers or potted plants. The bulb-producing phase of the industry has recently had its inception in this country and lily bulbs are now being grown in those sections of the United States which offer suitable soil and climatic conditions for this purpose.

The importance of the role played by plant diseases in connection with any of our common crops is too well established to merit further consideration at this point. In the case of lilies, however, the lack of sufficient knowledge with respect to the disease situation has led to the common practice of attributing all of the failures encountered with these plants to improper soil and climatic conditions, poor cultural methods, insufficient nutriment and the like. Believing that statements of this sort did not represent the true state of affairs, a fellowship was established in the fall of 1927 by The

Horticultural Society of New York, The Boyce Thompson Institute for Plant Research, The New York Botanical Garden and Cornell University for the purpose of investigating the various diseases of plants belonging to the genus Lilium. The committee in charge of the Fellowship was Dr. L. M. Massey of Cornell University, Dr. L. O. Kunkel of the Boyce Thompson Institute and Dr. A. B. Stout of the New York Botanical Garden. It soon became evident that most of the failures in connection with lily culture were due to definite organisms and viruses which infected the plants and caused disease.

It is the purpose of this article to present all of the available information in regard to those diseases of lilies known to be present in the United States. In the following discussion, the various diseases have been arranged in a sequence corresponding to the writer's opinion of their relative importance.

Mosaic*

Mosaic is the most serious and widespread disease of lilies at the present time. The earliest record of this malady is that by Stewart (22)**, who published observations in 1896 on a disease now known to be mosaic on *Lilium Harrisii*, the Bermuda lily. It is very probable, however, that the disease affected cultivated lilies at a much earlier date. The geographical distribution of mosaic may be said to be worldwide. It has been observed by the writer on over forty

*A technical report, including all of the data upon which the statements regarding this disease are based, will appear shortly as a Memoir from the Cornell University Agricultural Experiment Station on "A Mosaic Disease of Lilies."

**For references see under Literature Cited.

species of cultivated lilies and their varieties which were being grown in this country for the first time from bulbs produced in Bermuda, China, England, France, Holland, India, Japan, Russia and the United States. Mosaic has never been observed on species of lilies growing naturally in the wild. Wild lilies, however, are susceptible to the disease and will exhibit typical symptoms when inoculated with the causal virus.

The virus which causes the mosaic disease of lilies seems to be confined to species within the genus Lilium, with the single exception of the genus Fritillaria which also belongs to the family Liliaceae. Attempts to transmit the lily virus to a large number of other plants have not been successful and, similarly, attempts to transmit to lilies those viruses which cause mosaic diseases in other plants have thus far met with failure. It is possible that further work may extend the suscept range of the virus but at the present time it remains within the limits defined above.

Losses Due to Mosaic

The disease results in losses of various types. Inasmuch as lilies are used chiefly for the ornamental value of their flowers, the effect of mosaic upon the blossoms constitutes the most serious loss. Flowers produced by severely affected lilies are often of poor color and exceedingly distorted—so much so that they are worthless with respect to their commercial or ornamental value. There is also a marked reduction in the number of flowers produced by mosaic-diseased plants. Flowers from affected plants do not possess the shipping or keeping qualities of healthy blossoms.

Serious losses also result from diseased plants dying out in a year or two, leaving nothing to show for the original investment. From the standpoint of commercial bulb production, the stunting effect of the virus makes it more difficult to obtain bulbs of marketable size.

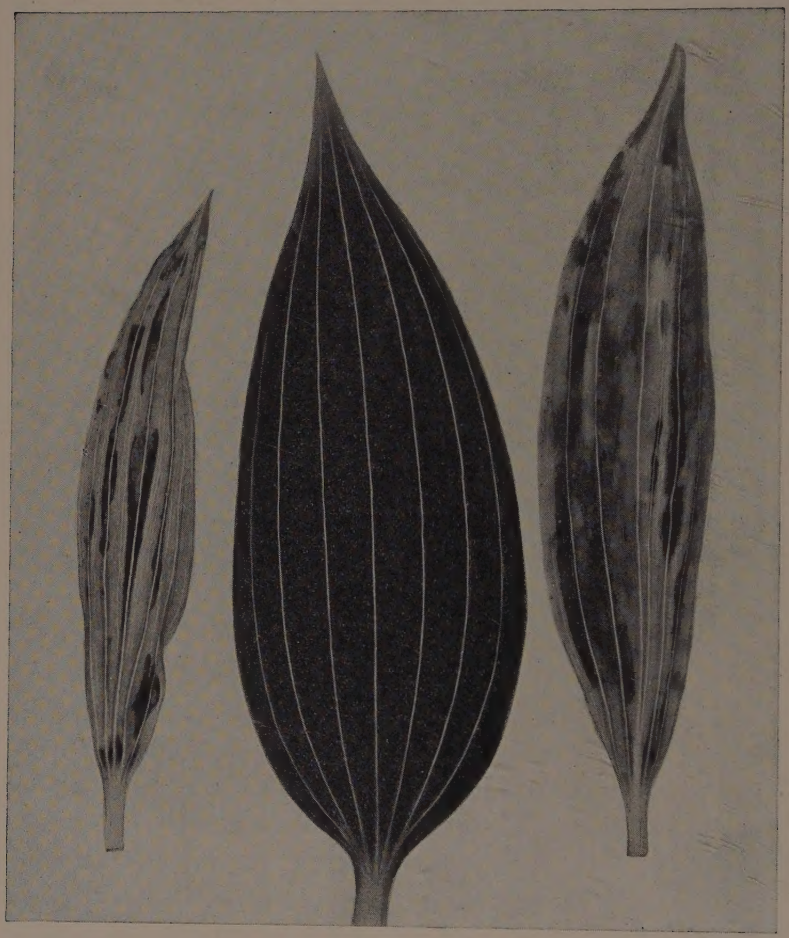


FIG. 1
Leaves from healthy and mosaic-affected plants of *Lilium speciosum rubrum*. Note mottling.

It is impossible to derive an accurate estimate of the losses caused by this disease except to state that they are frequently tremendous. The writer has observed plantings of lilies under field, garden and greenhouse conditions, in which from three to ninety per cent of the

plants were affected with mosaic. Having in mind the value of an ordinary lily bulb, the losses under conditions such as those described above amount to considerable.

Symptoms

Lilies affected with mosaic are easily distinguished on the basis of several different symptoms. In the first place, the leaves of infected plants are patterned with definite light and dark green mottled areas (fig. 1). According to the species of lily affected, this mottling may vary in intensity and type of pattern. Three general types of mottling have been observed. The first of these is best typified by varieties of *L. longiflorum*, the Easter lily. The mottling consists of regular or irregular light green areas which, as the leaves mature, often dry out and die to form small, linear, necrotic lesions. Leaves affected with this type of mottling are usually twisted, distorted and curled. Another type of mottling is exhibited by mosaic-affected plants of *L. auratum, L. canadense, L. superbum* and *L. speciosum* among others. In these cases, the chlorotic areas occur in elongate streaks of varying width and frequently extend the entire length of the leaf. Necrosis does not occur but a marked difference in leaf thickness is evident between the light and dark green areas. The leaves are not markedly malformed but are reduced in size. The third type of mottling which has been observed is characterized by rounded or irregular chlorotic areas which are scattered in a definite pattern over the leaf surfaces. This type of mottling is most common. The intensity of the pattern varies with the species or variety involved. The leaves of affected plants are not distorted or curled and the marked reduction in leaf size so typical of the second type of mottling is here not so evident.

Evidence has been obtained that these types of mottling exhibited by various species of lilies are due to differences in the plants af-

FIG. 2
Healthy and mosaic plants of *Lilium longiflorum formosum*. Note stunting and distortion.

FIG. 3 Healthy and mosaic-affected flowers of *Lilium auratum*. Note marked distortion of diseased flowers.

fected and not to different viruses. In other words, the virus which causes the mosaic disease of lilies appears to be the same in all of them. This has been shown by large numbers of cross-inoculations.

Another symptom exhibited by mosaic-affected lilies is that of stunting (fig. 2). The amount of stunting varies with the species and is also correlated with temperature. Thus, at a temperature of 80 degrees F. or higher there is a tendency for many of the symptoms of mosaic to be masked. Affected plants growing at this temperature, or higher, are less stunted and the mottling more difficult to see than similar plants growing at lower temperatures.

Mosaic lilies may frequently be detected at a distance by an abnormal dying of the leaves from the base upward. This often occurs several weeks in advance of the normal maturing of healthy plants. This premature death of the leaves, of course, results in a smaller bulb and one poorly equipped with reserve food for next year's growth, to say nothing of the future effect of the virus which it harbors.

Flowers produced by plants affected with the mosaic disease are frequently distorted (figs. 2 and 3), and not salable. In many cases the blooms tend to pucker and adhere at the tips of the perianth segments. The stamens and pistils are often distorted or aborted. The color of diseased flowers is frequently dull and faded.

Unfortunately, the bulb symptoms of mosaic-affected lilies are not particularly striking, thus making it impossible to sort mosaic from healthy bulbs in the packing houses before shipment. Mosaic bulbs may be smaller in size and often lack the crisp, fresh appearance of the healthy stock, tending on the other hand to be more or less flaccid and dry. A similar condition, however, can be induced by improper handling after digging or by poor storage conditions.

Pathogenicity

The causal factor concerned in the mosaic disease of lilies is a virus. The exact nature of all viruses, whether plant or animal, still remains obscure despite the large amount of research aimed at a solution of this problem. The ability of the lily mosaic virus to produce disease within these plants has been repeatedly demonstrated by many successful inoculation experiments. Healthy plants may be infected by inoculating with juice from diseased plants by means of hypodermic injections, scratching or abrading the leaves and by needle punctures. The most successful method is to puncture the stems with needles thru drops of juice expressed from well mottled leaves.

In addition to mechanical methods, the pathogenicity of the lily mosaic virus has also been proven by means of insect transmission. Thus it has been found that *Aphis gossypii* Glover, the common melon aphis, is an insect vector of this disease. Other insects present upon lilies have been tested in this connection, but thus far the results have been negative. Lilies inoculated with the virus by means of aphids or mechanical methods exhibit symptoms of the disease in eight to twelve days under the most favorable conditions. The melon aphis is also known to transmit the virus which causes the yellow flat disease of *L. longiflorum* (19), and Doolittle (3) has demonstrated the ability of this aphid to transmit the cucumber mosaic virus. That the cucumber virus and the lily virus are different has been shown by cross-inoculation experiments. There are also certain differences in the properties of the two viruses.

Seasonal Activity of the Virus

So far as is known, the virus which causes the mosaic disease of lilies passes its entire existence in direct association with the living suscept except for the time it is carried by the insect vector. There

is no evidence to show that the virus lives in the soil, nor that it may, in the absence of the aphis, pass from mosaic to healthy lilies planted in close proximity to one another.

The chief sources of primary inoculum in the spring are plants growing from bulbs previously infected with the virus. The melon aphis appears, thus far, to be the only insect concerned in the dissemination of the virus to healthy plants. As soon as the aphids appear in the spring they begin to feed. If an aphis feeds upon a mosaic lily it will then transmit the virus to the next healthy plant upon which it feeds. All stages of the aphis are able to transmit mosaic and it has also been shown that a single insect is sufficient to effect a successful inoculation.

Following its introduction into the tissues of the healthy plants, the virus passes up into the growing point of the stalk. In eight to twelve days the youngest leaves begin to show the characteristic mottling. With some lilies, infection with mosaic may be detected before the appearance of mottled leaves by a very noticeable clearing of the veins in those leaves which were partly mature when the inoculation took place. This clearing is striking in such forms as *L. auratum, L. speciosum, L. superbum, L. canadense* and others.

In connection with current season symptoms, a phenomenon known as "crook-neck" which has been observed among plants of *L. auratum* should be noted at this point. Stout (23) has observed and figured a sudden "blight" which frequently occurs during the summer especially on this species of lily. The phenomenon has not been observed until after the plants are in bud. The first symptom consists of a marked clearing of the veins in some of the partially mature leaves near the apex of the stem. Following this the upper leaves begin to yellow and fall to the ground. Similarly, the buds begin to blacken at their bases and drop. In the final stage, a

bare, crooked stem is the result (fig. 4). It is believed that crook-neck on *L. auratum* is the result of current season infection with the mosaic virus. This conclusion is based on many observations and experiments. The phenomenon has never been observed on plants grown from bulbs affected the previous season. The first symptom, clearing of the veins, is typical of current season infection with mosaic. Healthy plants of this lily in the bud stage, when inoculated with the virus either by mechanical methods or insects, invariably show crook-neck. Bulbs from plants showing this symptom the previous season, when grown the next year, have produced without a single exception new plants infected with mosaic. Although various fungi have been isolated at times from plants showing crook-neck, the isolations have not been consistent and inoculation experiments were entirely negative.

The secondary infections with mosaic, when they occur, are initiated and carried on in exactly the same manner as that described for the primary cycles. Plants affected late in the season fail to exhibit symptoms of the disease until the following year.

There is no evidence to indicate that the virus lives saprophytically. It must remain in intimate association with the living suscept in order to be infectious. In place of a saprophytic stage, the virus passes the resting period of the plant within the bulb.

Epiphytology

Aside from the masking of symptoms due to high temperature, ecologic and climatic conditions have not been observed to affect the responses of lilies to the mosaic virus. On the other hand, the effect of environmental conditions upon the insect vector is of extreme importance in determining the rate of spread. The prevalence of the melon aphis during any given season is largely dependent upon the presence or absence of the various insect parasites which

FIG. 4 Progressive stages of crook-neck on *Lilium auratum*.

prey upon this aphid. With normal weather, the parasites will keep the aphid population fairly low. Cool, moist weather following a backward spring, however, retards the activities of the parasites while favoring the rapid breeding of the aphids, so that serious infestations occur. Under such conditions, a rapid spread of lily mosaic may be expected provided a source of inoculum is present. Field observations over a period of years have shown this to be the case.

Control

Due to the fact that mosaic lilies apparently never recover from the disease and that no method is known by means of which affected plants can be cured, measures for control must of necessity be such as to prevent further spread of the virus.

Sanitation and Culture

Removal of the sources of inoculum, or in other words, roguing and destroying all mosaic lilies as soon as they are detected constitutes the most efficient means for combatting this disease. Lily growers may take advantage of the fact that in practically all cases the mosaic-affected plants can be detected and removed early in the season before the insect vector appears. The roguing should be done as soon as it becomes possible to distinguish the diseased plants from the healthy ones. The bulbs as well as the stems and leaves should be removed and destroyed, because otherwise self-propagation will occur and the young plants resulting from the affected mother bulb will serve as sources of inoculum the following season. It is necessary to remove all mosaic lilies regardless of species or variety since it has been shown that the virus from any given species can be transmitted with facility to practically any other species.

The results obtained by the Bermuda Department of Agriculture in their campaign to eradicate yellow flat and mosaic from the lily fields of Bermuda by means of efficient roguing are ample evidence that mosaic can be controlled in this manner. There appears to be no excuse for the relatively high percentages of diseased bulbs which are commonly put upon the market by growers in this country as well as in other parts of the world. The fact that this disease can be detected only by examination of the growing plants makes it apparent that importers and dealers in lily bulbs should not be held liable for the presence or absence of this disease in the bulbs they handle. The matter appears to rest squarely on the shoulders of the growers. The ultimate users of lilies should demand bulbs which are reasonably free from the mosaic disease.

In connection with cultural practices, care should be taken to use only sound, healthy stock for purposes of vegetative propagation. The use of mosaic-affected stock will result in diseased offspring. The bulbs to be used for this purpose should be carefully selected and marked before the plants are mature. When lilies come into bloom, there is a tendency for the leaves to become deeper green in color, thus making it difficult to select the healthy plants. If the grower waits too long before making his selections, he is bound to include mosaic bulbs in his propagating stock.

Since the virus is not transmitted in the seed, it is a good practice to grow these plants from seed whenever it is possible. Due to the fact that it takes longer to grow flowering bulbs from seed, many of the growers prefer the vegetative methods of propagation. However, the assurance of an absolutely mosaic-free stock is frequently well worth the extra time necessary to produce bulbs of flowering size from seed.

Under greenhouse conditions, where successful control of the

insect vector is easily obtained, roguing does not appear to be necessary. If environmental conditions are correct, some salable blooms will be obtained from mosaic plants which otherwise would be lost if such plants were destroyed. All spread of the disease can be prevented by fumigating the plants at frequent intervals with nicotine or cyanide. If these fumigations are neglected, however, aphids will multiply with great rapidity under the protection afforded them in the greenhouses and a marked spread of the disease will result.

Evidence has been obtained that mosaic plants forced at a mean day temperature of 75 degrees F., an increase of 10 degrees over the usual forcing temperature of 65 degrees F., will produce flowers of a better quality. Under these conditions, mosaic-affected lilies produce more flowers per plant with less distortion of the leaves and blooms. If the percentage of mosaic within the house is greater than fifty per cent, it is believed that forcing the lilies at the higher temperature will prove profitable.

Control of the Insect Vector

Except in greenhouses, control of the insect vector of lily mosaic does not appear to be practicable. Under field and garden conditions, attempts to prevent the dissemination of the virus by treating the plants as often as once a week with nicotine compounds to keep them free from aphids have not given satisfactory results. In fact, the disease spread just as rapidly among the treated plants as it did among those which were not treated. This is not surprising when one considers that this particular species of aphid infests a large number of different suscepts, many of them common weeds and plants of other types. Another factor which must be taken into consideration is that this aphid, under optimum conditions, produces the winged form in great abundance. These alate forms are natur-

ally migratory and fly about visiting plant after plant. Soon after lilies have been dusted or sprayed with nicotine, new aphids have been observed feeding upon them.

Resistant Species

A marked degree of resistance to mosaic on the part of any particular lily has not been observed during the course of these studies. Certain observations made in the field, however, have shown that under apparently uniform infection conditions, some species show a much lower percentage of current season infection than do other nearby species. The virus appears to be disseminated more rapidly among plants of *L. auratum, L. speciosum,* and *L. tigrinum* for instance, than among plants of *L. canadense, L. Hansoni,* or *L. regale* growing in the same field. It is believed that the insect vectors avoid the latter species for some obscure reason. This belief is strengthened by the fact that certain of the species which largely escape inoculation in the field have been found by means of mechanical inoculation under controlled greenhouse conditions to be just as easily infected with the virus as any other species.

Botrytis Blight*

Considering the fungous diseases of lilies as a whole, Botrytis blight is undoubtedly the most serious and troublesome. Its advent is especially feared by many commercial producers of these bulbs. When conditions are favorable for its growth and development, the fungus responsible for this disease may completely ruin an entire crop of lilies in the space of but a few days.

*A technical paper including experimental data obtained by the writer in connection with the Botrytis disease of lilies is now in preparation .

The disease was first described on *L. candidum* by H. Marshall Ward (24) in 1888. Soon after, its occurrence was noted in Bermuda (Kean 11). Subsequent references in the literature indicate that the disease is present in practically all regions where lilies are grown. Under the conditions obtaining in the Eastern United States where the writer has made his observations, not a single species has been found to be entirely free from this disease. There are, however, great differences in the degrees of susceptibility. *L. longiflorum, L. candidum, L. chalcedonicum,* and *L. testaceum,* a hybrid between the latter two species, have been found to be the most susceptible to Botrytis blight. Certain species, among them being *L. auratum, L. canadense, L. croceum, L. davuricum, L. speciosum, L. superbum,* and *L. washingtonianum,* while not as susceptible as those mentioned above, have been observed at various times to be severely affected. A few species such as *L. callosum, L. concolor, L. Hansoni, L. japonicum, L. martagon, L. pyrenaicum,* and *L. Willmottiae* appear to be more resistant. In some instances, certain varieties within a species are noticeably more resistant to the disease than others. It should be remembered, however, that under optimum conditions for disease development, serious injuries may result with any lily.

The losses which occur as a result of this disease are various. The most important in this respect is undoubtedly the injury to the leaves which so weakens the plants that they are unable to produce strong, vigorous bulbs for the next season's growth. When climatic conditions are such that an epiphytotic occurs, the more susceptible species and varieties are frequently killed back to the surface of the soil. In greenhouses as well as under field and garden conditions, the flowers may become affected thus rendering them unsightly and useless from the commercial standpoint. If the buds become infected previous to opening, they are often completely rotted.

Symptoms

Botrytis blight exhibits different types of symptoms depending upon the age and condition of the affected plants at the time of infection. When the lilies are young, six to eight inches in height, apical blight frequently occurs. The growing points of the young stems are destroyed and the plants are unable to make further growth during the season.

The second type is the common leafspot symptom. Its severity depends upon the size and number of spots per leaf and is directly correlated with weather conditions and the degrees of susceptibility of the plants affected.

The third type, bud rot or flower blight, occurs later in the season. It may follow the normal upward progress of the foliar spots or may occur in the absence of leafspots. In the latter case, the inoculum comes from nearby affected plants. The buds or the flowers may be attacked at any stage of development. Due to the succulence of these organs, this type of the disease is by far the most rapid and devastating in its effect.

The most typical and common symptom, spotting, is confined largely to the foliage. The spots (fig. 5) are usually circular or oval in shape and vary greatly in size. In most cases, the color of the spots is orange or reddish-brown. However, with certain species such as *L. canadense, L. Grayi, L. Henryi,* and *L. pardalinum* the spots have light colored centers surrounded by a definite reddish-purple margin which then grades off into the normal green healthy tissue. In some lilies such as *L. candidum, L. testaceum, L. chalcedonicum,* and *L. longiflorum,* the spots may have an indefinite margin, the line of demarcation between healthy and diseased tissue being merely a slightly darker colored water-soaked zone. During periods of hot, dry weather, the fungus within the leaf tissues ceases

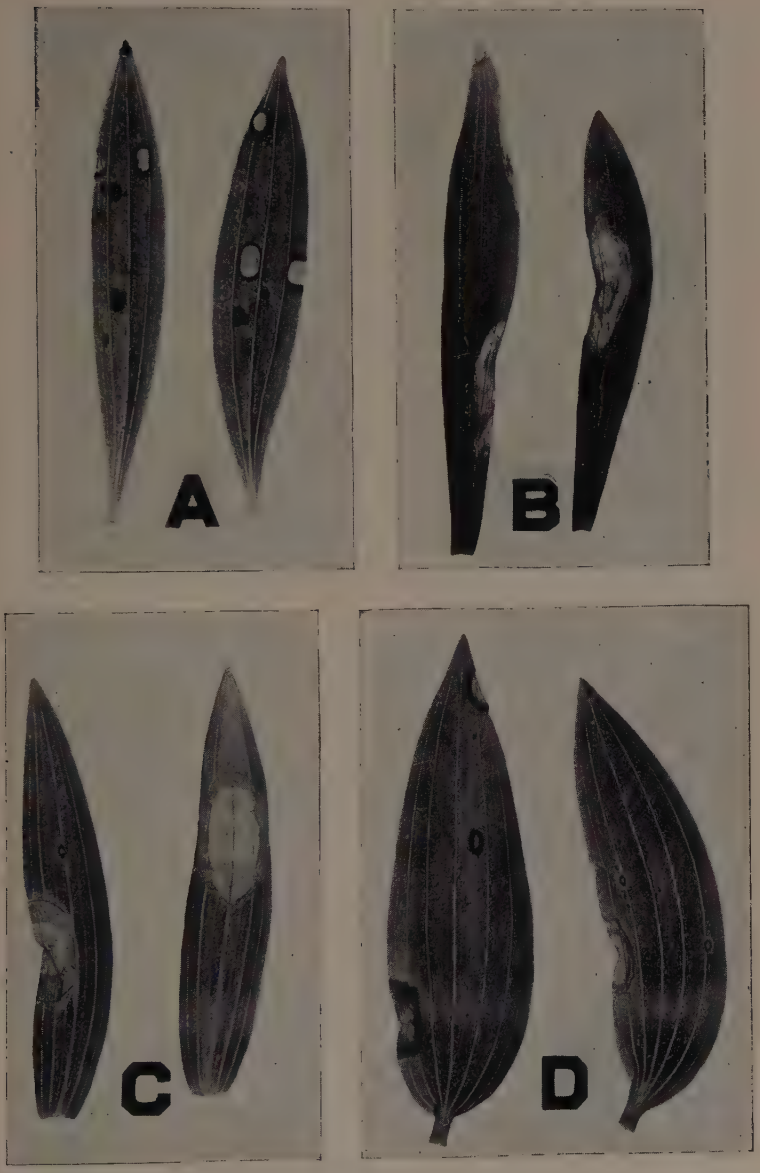


FIG. 5
Botrytis leafspots. A. *Lilium canadense.* B. *Lilium chalcedonicum.* C. *Lilium umbellatum,* Golden Fleece. D. *Lilium speciosum rubrum.*

active growth and the spots soon dry out. In this condition they are thin, brittle and have a characteristic translucent aspect.

In cases of severe infection, many spots may occur on a single leaf and during the course of enlargement they ultimately coalesce and include the entire leaf resulting in the typical blighted appearance shown in figure 6.

When stem lesions occur, they are very similar to those already described on the leaves.

Lesions on the buds or flowers (fig. 7) are usually brown in color and are more irregular in shape. They are frequently larger in size and the margins appear to advance more rapidly than do those on the leaves or stems. If weather conditions inhibit further growth of the fungus and prevent complete rotting of the buds, the flowers when they ultimately open are usually distorted.

Bulb lesions caused by the Botrytis fungus have not been observed. In rare instances, sclerotia have been observed between the bulb scales. However, such bulbs were not markedly injured.

Etiology

The Botrytis blight of lilies is caused by the fungus, *Botrytis elliptica* (Berk) Cooke. Westerdijk (25) has recently reported that this is the species concerned in the Botrytis disease of lilies in Holland. Wright (28) mentions what appears to be the same species in Great Britain. The writer has isolated strains of Botrytis from over thirty species of lilies in this country and with two exceptions these strains were pathogenetically and morphologically similar. The two exceptions were non-pathogenic forms. Spore measurements and cultural characters agree with those reported by Westerdijk and Wright. It would appear, therefore, that the European and American lily blights were caused by the same fungus.

FIG. 6 A planting of *Lilium candidum* severely affected with Botrytis blight.

FIG. 7 *Lilium regale* showing effect of Botrytis blight on the flowers.

The pathogenicity of *Botrytis elliptica* was first demonstrated by H. Marshall Ward in his work with it on *L. candidum.* Using spores taken from lesions on the leaves, he found that they were capable of causing infection with or without the presence of wounds. The first evidence of infection appeared 20-48 hours after the time of inoculation.

The writer has made numerous inoculation experiments with different strains isolated from various species of lilies. In the absence of wounds, with a saturated atmosphere and at the optimum temperature of 60 degrees F., the first evidence of infection, tiny watersoaked areas, have been obtained in the brief time of ten hours by atomizing spores on the leaves of healthy plants. In other experiments it has been demonstrated that strains of the fungus isolated from various different lilies are alike in their virulence and ability to produce disease in any given species.

Life History

The first infections in the spring are initiated by conidia which may arise from at least two sources. The most common of these are the overwintered sclerotia. Sclerotia have been observed in a few instances on the bulbs of certain lilies. During the summer, they are formed on infected perianth segments of flowers which have fallen to the ground. They have also been observed on diseased leaves and stalks. These small, black sclerotia winter over and produce conidia the following spring. It seems very probable that these tuber-like bodies constitute the chief sources of primary inoculum each season.

In the case of a single lily, *L. candidum,* a rosette of basal leaves is put forth in the fall and these remain green during the winter. Botrytis spots have been noted on these leaves in the fall and also

in the spring. Plants of this species, when affected the previous autumn, are undoubtedly sources of primary inoculum in the spring.

In several instances, new lots of bulbs have been carefully examined to be certain that they were free from sclerotia of the Botrytis fungus. They were then planted in soil where lilies had never been previously grown. Despite this, and with no nearby source of inoculum, the disease has appeared the following spring. The source of inoculum in these cases has not been determined.

Conidia produced by these various sources constitute the primary inoculum and are splashed by rain or carried by air currents to the leaves of healthy plants. The lower leaves are always the first to show signs of infection. Under greenhouse conditions, careless watering and drafts are responsible for practically all of the dissemination which occurs.

Upon reaching the leaves, the conidia germinate readily, provided sufficient moisture is present. Penetration occurs directly through the cuticle (Ward:24). During repeated observations, the writer has failed to see a single germ tube enter the leaf tissues by way of the stomata. Penetration may take place through the lower as well as the upper leaf surfaces. After gaining entrance to the leaf tissues, the fungus grows rapidly and the surrounding plant cells are soon killed, presumably by a toxin. When external conditions are correct, the formation of spores takes place. Certain of the fungous hyphae within the leaves push out through the upper or lower leaf surface and at the tips of these branches the conidia are borne in bunches. This imparts to the infected leaves or buds the familiar "gray mold" appearance.

The secondary cycles of infection appear soon after the production of conidia from the lesions of the primary cycles. The severity

and number of secondary cycles vary with climatic conditions. As in the primary cycles, wind and rain are the chief means of conidial dissemination.

Epiphytology

Temperature and moisture are the two most important factors which influence the severity of this disease. Kean (11) in some observations on Botrytis blight as it occurs in the Bermuda lily fields states that the warm days and cold nights so prevalent in Bermuda result in the precipitation of a heavy dew upon the leaves and under such conditions the fungus spreads rapidly and the plants are severely affected. The heavy dews so common on Long Island are responsible for the epiphytotics of this disease which occur among the lilies on that Island during the summer months. Conidial production invariably occurs under conditions of high humidity. With warm dry weather, spore production is inhibited, further growth of the fungus within the plant tissues is frequently stopped, and the disease becomes of little consequence. Relatively cool night temperatures aside from promoting precipitation of dew also aid the fungus in effecting penetration of the plant tissues. It has been shown experimentally that 60 degrees F., is the optimum temperature for infection to occur. Once the fungus has entered the plant, however, a warmer temperature, 70 degrees F., is the optimum for further growth and development.

Lilies planted in low and shady places are always more severely affected with Botrytis blight than those growing in higher and more sunny situations. This may be accounted for by the fact that dew tends to collect upon the foliage and other plant parts in the lower situations and the lack of sunlight does not permit of a rapid drying

in the morning. Such conditions are optimum for infection by this fungus and should be avoided when planting lilies.

Under greenhouse conditions, it frequently happens that a period of cloudy wet weather ensues in the fall before the steam has been turned on. When this occurs and if a source of inoculum is present, lilies grown at this time are often subject to an epiphytotic of the disease. Despite the greatest care in watering, climatic conditions of this nature promote and maintain a very high relative humidity within the houses and as a consequence the disease becomes extremely serious. Cases have been observed in which the entire crop was destroyed.

Control

Eradicatory measures are of great importance in the control of this disease. When the pathogene has become established in any field or garden, all leaves and stems of affected plants should be collected and burned before they decay. This serves to eliminate certain of the sources of primary inoculum which otherwise would initiate the disease again the following spring. When lilies are growing in an ornamental garden it is frequently worth while to pick and destroy all leaves and buds as soon as they give evidence of being infected. This will materially lessen the severity of the secondary infections. When bulbs are being produced commercially, it is often the custom of certain growers to go through the fields and disbud the plants, thus promoting the formation of larger bulbs. Any buds removed in this manner should be carried away from the fields. Ogilvie (15) reports that in Bermuda the fungus has frequently developed saprophytically among heaps of withered buds and flowers which have been thrown on the edges of the fields. Air currents then carried the spores back into the fields of healthy plants and serious results followed.

In greenhouses, removal of the primary infections on the leaves and buds will do a great deal toward lessening the amount of the disease during any current season. If a second crop of bulbs is to be forced in the same soil, great care should be taken to remove and destroy all plant debris resulting from the first crop. Many of the larger forcers of lily bulbs use their bench soil but once. As far as Botrytis blight is concerned, this practice is much to be desired. The humidity within the houses should be kept as low as possible. If climatic conditions at certain times of the year make it impossible to keep the humidity low, it will frequently pay a grower to start firing his houses in order to dry them out. Great care should be exercised in watering the plants. Many growers are lax in this respect, thus wetting the foliage and increasing materially the humidity within the houses.

The use of certain fungicides offers an excellent means of control for this disease. In field experiments already conducted, sulfur fungicides have not given satisfactory control. On the other hand, copper-lime dust and bordeaux mixture have proved to be very beneficial. The most important consideration in the use of either of these fungicides is to get an application on the plants *before* any infection has occurred. The disease is extremely difficult to control once it has gained much headway. The number of applications necessary for any given season will depend upon the susceptibility of the lilies being grown and upon weather conditions. If the season is dry, two or three applications will suffice. When wet weather prevails, however, it is often necessary to apply the dust or spray at least once every two weeks. All new growth must be kept protected.

Bordeaux spray (4-4-50) has given excellent control of the disease. Applications may be made at any time without injury to the plants. To obtain the best results, however, the spray should be used prior to periods of rain in order to afford the plants the maxi-

mum amount of protection at the time when spore production and dissemination is taking place. The spray should be so directed that both upper and lower leaf surfaces are covered.

When using copper-lime dust, it is essential that the plants be covered with dew at the time the dust is being applied. Water induces a chemical reaction which makes the dust effective. When using either the spray or dust, it should be remembered that several light applications will give better control of this disease than one or two heavy applications.

Yellow Flat*

For our knowledge of the "yellow flat" disease of lilies we are indebted to Mr. Lawrence Ogilvie, formerly plant pathologist of Bermuda. He made the study of this disease one of his major projects while in Bermuda and the results of his work have been published in the Annals of Applied Biology (19).

Yellow flat is a virus disease and with the possible exception of *L. Batemanniae* seems to be confined entirely to *L. longiflorum* and its varieties. In Bermuda it has been one of the most serious diseases in connection with lily culture and in conjunction with the mosaic disease was responsible for the disastrous collapse of the Bermuda industry shortly after 1896. Both Mr. Ogilvie and the writer have observed yellow flat on forced *longiflorum* bulbs imported into this country from Japan. The disease is also known to be present in those regions of this country where Easter lily bulbs are being grown commercially in the field.

*The name of this disease has been changed recently to "rosette" (21). However, the writer prefers to continue using the name "yellow flat" because the disease was first described under that heading, it is the name most familiar to the growers and it also brings to mind more satisfactorily the picture presented by affected plants.

FIG. 8
Yellow flat as it appears in the greenhouse on *Lilium longiflorum formosum*. Healthy plant on the left.

Diseased plants (fig. 8) have the general appearance of a flat rosette in contrast with the healthy plants which are pyramidal in shape. Affected plants lack the normal green color, being paler green instead. The chlorosis is general and does not occur in streaks or spots. The leaves, especially the younger ones, are curled downwards and may also be twisted sideways, thus becoming distorted. Affected plants are markedly stunted due to a characteristic shortening of the internodes. The number of flower buds is reduced,

many plants often being entirely blind. When affected bulbs are forced under glass, any flowers obtained from them are useless from the commercial standpoint because of their splitting, failure to open or marked distortion.

The virus which causes yellow flat has a marked effect on the size and shape of the bulbs (Ogilvie:19). An affected bulb has inner scales which are tightly drawn together, the circumference of the bulb is smaller and there is a noticeable reduction in height. Such bulbs also have a tendency to split, resulting in size reduction from year to year until finally the bulbs are little larger than peas.

As is true with most virus diseases, affected plants never recover. Some cases of apparent recovery have been observed from time to time but these have been due to masking induced by shade or high temperatures. Such bulbs when grown under normal conditions again reproduce typical symptoms of the disease.

Under field conditions, yellow flat usually appears in patches and it will often be noted that an exceedingly stunted plant occupies the center of the patch. This plant resulted from a bulb which was previously infected and has served as the source of inoculum for this particular location. Ogilvie (19) has shown that the virus which causes the yellow flat disease of lilies is transmitted from diseased to healthy plants by the melon aphid, *Aphis gossypii* Glover. The virus is not transmissible by mechanical methods and there is no evidence that it spreads through the soil. Thus the melon aphid appears to be the sole means of transmission.

Current season symptoms are typical of those described above. Spread may occur at any time during the life of the plant although plants affected late in the season do not exhibit symptoms until the following year.

There is ample evidence in Bermuda that satisfactory control of this disease can be obtained provided the proper measures are followed. If a stock of bulbs is badly infected with yellow flat, it should be discarded and a start made with a new stock or with bulbs propagated from plants marked and known to be healthy. Affected plants should be carefully watched for and rogued out as soon as detected. The bulbs, as well as the plants, should be removed and destroyed. Cases are known in Bermuda where growers have thrown discarded plants on the edges of their fields. Such plants have often become infested with the insect vector and the virus has been carried back into the fields again. Ogilvie (19) states that in Bermuda the fields may be kept free from aphids by spraying or dusting with nicotine compounds. In addition to the above measures it should also be pointed out that any form of vegetative propagation will result in diseased offspring provided the parent bulbs were previously affected with yellow flat. Accordingly, all propagation of young stock should be conducted only with bulbs which are known to be healthy.

When *longiflorums* are being forced in greenhouses, plants affected with yellow flat should be removed and destroyed at once. They will never produce salable flowers and merely constitute a menace to the health of the other lilies. When the proper insect vector is present, as it often is, spread of the disease can occur as readily and as rapidly in the greenhouse as it does in the field.

Bulb Rots

A problem of extreme interest to all concerned in the lily industry is that of the various rots which affect the bulbs in storage or in transit. The situation is indeed a vexing one and the losses are frequently considerable. Repeated examinations of case lots of bulbs,

both on arrival in this country and after having been cold stored during the winter, have revealed losses of from 5 to 100 per cent. Losses as high as 100 per cent are rare but it is practically impossible to carry case lots of *L. japonicum* or *L. rubellum* through the winter without losing at least 50 per cent of the bulbs. With *L. auratum*, the losses probably average about 25 per cent. Other more or less susceptible lilies are *L. Batemanniae, L. croceum, L. elegans*, and *L. speciosum album*. Infrequently, rot has also been observed on bulbs of *L. canadense, L. cordifolium, L. giganteum himalaicum, L. martagon, L. medeoloides, L. monadelphum, L. regale, L. testaceum*, and *L. umbellatum*. It is very likely, that under favorable conditions, bulbs of still other species will be found to suffer.

There seems to be no correlation between the type of packing medium used for the bulbs and the amount of rot which may occur. Bulbs of *L. monadelphum* from Russia packed in crushed charcoal have been observed in a rotted condition upon arrival in this country. Similarly bulbs packed in Japanese red sub-soil, washed coral sand from Bermuda, peat moss, sphagnum or excelsior have also rotted during transit or in storage.

Two fungi are chiefly concerned in these transit and storage rots of lily bulbs. One of these, *Rhizopus necans* Mass., has already been reported by Massee (13) as causing a serious rot of lily bulbs imported into England. He described the symptoms, isolated the pathogene concerned and proved its pathogenicity.

The Rhizopus organism is the one which causes rotting of the bulbs while they are in transit. This fungus needs a fairly warm temperature to become actively pathogenic. As such, it is not the cause of injury to lily bulbs while they are in cold storage. Slightly wounded bulbs of *L. auratum* at room temperature have been completely rotted in 48 hours when inoculated with this fungus. The

rapidity with which it destroys a bulb explains why it is that in many instances dealers ship what appear to be perfectly sound bulbs to a customer only to learn that they arrived in a thoroughly rotted condition. Strains of Rhizopus isolated from different species of lilies will rot healthy bulbs of any given single species with equal facility. Infections have been obtained, however, only by inoculation through wounds.

Bulbs affected with Rhizopus exhibit a soft, mushy type of rot having a slightly sour odor. Infected areas on the scales have a watersoaked appearance and are slightly darker in color than the healthy portions. Completely rotted bulbs, due to their soft, wet condition, become caked with soil or whatever the packing medium may be and are easily detected in this manner. In many cases they are covered with a mass of white mycelium and black sporangia full of spores. Initial infections often occur on wounded scales. The fungus grows down through the scale into the basal plate from whence it enters and destroys the remaining scales of the bulb. In many instances, the fungus gains entrance through the numerous wounds made when the basal roots are cut away prior to packing the bulbs for shipment.

The second organism concerned in these bulb rots is a species of *Penicillium.* Infection and development of the fungus take place in a manner similar to that already described for the Rhizopus. The Penicillium rot is not soft in type. Lesions on the scales are usually sunken and often deep brown in color. The fungus develops rather slowly, often requiring two or three months to entirely destroy a bulb. Well rotted bulbs are punky in consistency and whitish when broken open. The fungus fruits profusely on the outer scales and between the inner scales of affected bulbs. In this condition the pathogene has the typical blue-green color so commonly noted.

The Penicillium rot organism continues to destroy the bulbs while they are in cold storage. In fact, this fungus appears to cause all of the losses which occur while the bulbs are in storage.

Experiments designed to control the various bulb rots have been under way for some time. Since most of the evidence indicates that the bulbs become infected after being dug, it was believed that a bulb treatment of some sort might give satisfactory control. Massee (13) states that submergence for a short time in a one per cent solution of corrosive sublimate or salicylic acid kills the spores and prevents infection. Neither of these solutions injured the bulbs provided they were not treated for longer than fifteen minutes. In the writer's experiments it was believed that a liquid dip would not be satisfactory inasmuch as the structure of lily bulbs makes it difficult to dry them rapidly. Accordingly, various dust treatments were attempted. Certain lots of bulbs were dusted in New York before being placed in cold storage while in other instances, the materials to be tested were sent to Japan and the bulbs were treated before being packed for shipment. It was soon determined that dusts containing sulfur or copper as the toxic principle gave little or no control. However, with certain of the organic and inorganic mercury compounds, excellent control was obtained. In some experiments, bulbs dusted with these materials had less than one per cent rot while the untreated checks varied from 25 to 40 per cent. Some of the mercury dusts caused injury in the form of a marked discoloration of the bulb scales. As a result, these experiments have been continued in an attempt to reduce the amount of injury. Lighter applications have been made, the per cent of mercury in the dusts has been reduced and certain new forms of mercury are being tested. Until the results of these experiments have been obtained and the bulbs so treated have been grown in the field to check against injury in any form, it is

not considered advisable to recommend the use of any particular dust. A full account of these experiments together with the final results and conclusions will be given in a later publication.

Aside from the value of a dust treatment in controlling the bulb rots of lilies, those engaged in handling these bulbs, especially the susceptible varieties, should observe all possible precautions in order to avoid wounding them. Rotted bulbs should not be allowed to accumulate within packing sheds or warehouses while bulbs are being packed for shipment. Packing media should not be kept too moist and should be of such a nature that they do not readily heat. Basal roots should be left on the bulbs whenever possible since the removal of such roots affords the rot fungi an excellent means of entrance. Wrapping the bulbs in pieces of waxed paper may aid in preventing spread of the fungi concerned from diseased to healthy bulbs.

The Bulb Mite

Of the various mites which are known to infest bulbs, *Rhizoglyphus hyacinthi* Banks, the bulb mite, is probably the only one which is the cause of any considerable injury. This particular mite is known to attack healthy bulbs of various types such as lily, narcissus, hyacinth, tulip, and crocus. The mite appears to be widely distributed (McDaniel:14) having been reported from practically every state in this country. It is also frequently detected in shipments of bulbs coming to the United States from Europe and the Orient. The writer has observed mite-infested lily bulbs shipped from various points in this country as well as from other parts of the world. Ogilvie (16) reports their presence on bulbs of *L. Harrisii* in Bermuda.

Although it is generally conceded that the bulb mite is not especially injurious on tulips, crocuses and hyacinths, such does not appear to be the case with lilies. The writer has observed lily bulbs of many different species under field and greenhouse conditions in which infestation with the bulb mite has resulted in marked injury. Ogilvie has observed serious injury on *L. Harrisii* in Bermuda.

The loose structure of lily bulbs renders them particularly susceptible to the mite. In most instances, the mites are found in and around the basal plate of a bulb in the early stages of infestation. The basal roots are destroyed and have a very characteristic thread-like, fibrillar appearance. The mites increase rapidly and the basal plate is soon destroyed following which the bulb breaks up into a mass of infested scales. Cases have been observed in which the mites have burrowed several inches up into the stem. Severe infestations result in death of the plants.

Aside from the direct injury caused by the feeding of the mites, the resulting wounds undoubtedly offer means of entrance to various fungi and bacteria which aid in the final deterioration of the bulbs. In general, the more severe cases of mite injury have been observed in greenhouses where the conditions under which the bulbs were being forced undoubtedly proved beneficial to the mites as well.

This pest is relatively small and needs careful scrutiny to be seen without the aid of a lens. The adults are usually yellowish-white tinged with pink and appear to be transparent. The legs and mouth-parts are reddish-brown in color. Eggs are deposited by the females on or between the bulb scales. Depending upon external conditions, the eggs hatch within six days. After several quiescent periods and molts the young nymphs become adults. In many cases, healthy bulbs become infested in the field. When such bulbs are stored under conditions suitable to the mites, the bulbs deteriorate rapidly

and serve as foci for further infestations. Importers of foreign bulbs have frequently suffered heavy losses due to mites which have multiplied during delays in transportation.

Any migration of the mites from infested to healthy bulbs probably occurs following the formation of the so-called hypopus stage. The adult mites are more or less sluggish but in the hyopopus stage, which develops under unfavorable conditions, the mites appear as small, active individuals with a tendency to wander from place to place. In this stage they are also prone to attach themselves by means of ventral suckers to any moving object. They have been observed attached to the larvae of many different insects and dissemination undoubtedly takes place in this manner.

No satisfactory means of control for this pest has been developed as yet. Fumigants have not proven effective and where hot water alone has been used, the temperature necessary to kill the mites has also resulted in injury to the bulbs. Garman (7) in some experiments with Narcissus, states that the mites may be controlled by dipping infested bulbs for ten minutes in a 1-400 solution of nicotine sulphate heated to 122 degrees F. It is not known whether a treatment of this sort would be safe or effective for lily bulbs.

There are, however, certain field practices which will be of aid in keeping this pest under control. The bulbs should be grown on soil which has been well prepared and carefully drained. In planting, use only the sound, healthy bulbs. Sickly plants, if examined and found to be infested, should be destroyed at once. Where infestations have been serious, crop rotation should be practiced. Under greenhouse conditions, fresh soil should be used for each succeeding crop of lilies. When bulbs are out of the ground, they should be kept in storage at a temperature of 35 degrees F., if possible. Low temperatures are unfavorable to the development of the mites.

There is a need for further work in connection with bulb mites on lilies. The role, if any, played by these pests in the dissemination of other diseases should be studied. The possibility that the wounds caused by the feeding of the mites are correlated with the incidence of the various types of bulb rots also needs consideration. Finally, a satisfactory treatment is needed, whereby infested lily bulbs can be freed of these pests before being planted out.

Limber Neck

Griffiths (9) describes a phenomenon occurring among certain lilies to which he applies the term "limber neck." The stems of affected plants collapse and wilt at a point a few inches below the growing tip (fig. 9). This collapse usually occurs when the plants have attained a height of one or two feet. Griffiths reports this condition among lilies growing in moist, shady places and notes its prevalence shortly after periods of low temperature.

The writer has observed limber neck under conditions such that low temperatures and frost injury could not be considered the causal factors. The disease has been commonly noted on fall crops of *L. speciosum* and its varieties being forced under glass. It has also been seen to occur among plants of *L. auratum* growing in a greenhouse in mid-summer. Under field conditions, the phenomenon has been observed on *L. auratum, L. candidum, L. chalcedonicum, L. croceum, L. martagon, L. monadelphum, L. pyrenaicum, L. regale,* and *L. testaceum*, growing in the open as well as in the shade.

In general this disease may be considered of minor importance, especially under field conditions. In greenhouses, losses of five per cent have been observed. Following the collapse of the stem at some particular point the upper portion of the plant, of course, wilts

FIG. 9
Greenhouse-grown plants of *Lilium speciosum rubrum* affected with limber neck.

and dies, thus preventing flower formation. Below the point of collapse, however, the plant does not appear to be injured except that bulb growth will be considerably lessened due to the loss of some of the foliage. The upper portions of certain plants affected with limber neck have been removed and it has been noted that the remaining parts of the plants have continued to live and function during the rest of the season. Under greenhouse conditions, plants affected with the disease appear here and there all over the house. No evidence has been obtained which would indicate that the disease was spreading from affected to nearby healthy plants. Limber neck plants when removed from the soil often have few or no basal roots while nearby healthy plants show normal root development. Experimentation will be necessary, however, before it can be stated that the lack of basal root development is a factor in the disease.

The exact cause of limber neck still remains obscure. Numerous attempts to isolate a causal organism have been made. In most cases the plates remain sterile. A few species of fungi have been isolated but with no degree of consistency and inoculation experiments with these fungi have not given positive results. Having in mind the possibility that the disease might be virus in nature, bits of collapsed stems have been inserted into healthy stems of the same species of lily but again the results were negative. Further studies are needed.

Certain similarities between the symptoms exhibited by lilies affected with limber neck and tulips having the "Umfallenkrankheit" (Pinkhof :20) should be pointed out at this time. In this disease of tulips, generally held to be physiological in nature, the flower stalks collapse at a point a few inches below the base of the flowers. The cause of this tulip disease is not completely understood at the present time. It occurs chiefly in greenhouses and losses as high as 100 per cent have been observed. High temperatures appear to be more important in augmenting the disease than high humidities.

Rust

Although rust diseases of various ornamentals such as hollyhocks, carnations, and snapdragons are often serious in nature, lily rust is of minor importance at least in the Eastern United States. The writer has not observed this disease in a single instance among cultivated lilies. Reference to the herbarium in the Department of Plant Pathology at Cornell University reveals the fact that the lily rust has been collected on *L. canadense* in New York State, but only rarely. Griffiths (9), however, states that the rust is often serious in certain regions along the Pacific coast. Very likely environmental conditions are more favorable to the fungus in that part of the country.

The cause of this disease is *Uromyces Holwayi* Lagerh. of which *Uromyces lilii* Clinton is a synonym (Arthur:1). Affected plants exhibit small circular or elliptical pustules chiefly on the under surfaces of the leaves or along the stems. In cases of severe infection these powdery, brown pustules may aggregate to form larger areas. The fungus lives its entire life cycle on the lily.

According to Griffiths (9) *L. candidum, L. humboldti, L. parryi, L. washingtonianum, L. pardalinum* are particularly susceptible. He also mentions the native *L. columbianum* as being badly rusted all through the Northwest. In another publication (8) *L. longiflorum* and *L. regale* are held to be more or less resistant.

Various suggestions for control have been offered such as removal of plant debris in the fall and persistent spraying with Bordeaux mixture. Considering the efficiency of sulfur in controlling rust diseases on other plants, it is very likely that excellent control of the lily rust can be obtained by dusting with sulfur.

Frost Injury

Late frosts in the spring are liable to be the cause of injury to lilies. This is especially true of certain types such as *L. candidum, L. Hansoni, L. regale,* and *L. Henryi* which begin to appear soon after the ground has thawed. If the frost is particularly heavy the plants are very often completely killed back. With the lighter frosts, a condition known as "puffy leaf" (Griffiths:9) frequently results. The plants are usually dwarfed due to the fact that the growing point has been killed. The leaves (fig. 10) are distorted and thicker than usual. This thickening, it will be noted, is caused by the separation of the lower epidermis from the tissues above. The fact that the separation may not occur over the entire leaf surface gives rise to a condition of unequal tension which results in marked distortion.

FIG. 10
Puffy leaf caused by frost injury on *Lilium Henryi.*

Griffiths (9) reports having seen puffy leaf on *L. Hansoni, L. regale,* and *L. Henryi.* He also states that it is not uncommon to find plants of *L. longiflorum, L. candidum,* and members of the *humboldti* group similarly affected. In the Eastern United States the writer has observed puffy leaf on *L. Henryi* and *L. regale.* With other lilies where frost injury has been a source of trouble, the plants have been completely killed back.

Mulches of various types often serve to protect the young shoots of lilies from frost injury in the spring. Moving the plants to a slightly higher elevation may aid in preventing injury of this type as indicated by Griffiths (9). He mentions an instance in which *L. Henryi* was severely injured in a certain location while plants growing on a ridge twenty feet higher were not affected.

Stump Rot

Stump rot, caused by a fungus belonging to the genus Phytophthora, was first described by Whetzel (26) as occurring on *L. Harrisii* in Bermuda. It has been observed by the writer on plants of *L. longiflorum eximium* (*L. Harrisii*), *L. Longiflorum formosum, L. longiflorum giganteum,* and *L. speciosum rubrum* growing under glass in this country. In rare instances, it has been seen in the field on *L. candidum, L. Hansoni, L. pyrenaicum,* and *L. testaceum.* Whetzel (26) cites counts showing losses as high as 43 per cent in Bermuda. Ogilvie as well as Cunningham, in various numbers of the Agricultural Bulletin published by the Bermuda Department of Agriculture, mention serious outbreaks of this disease.

According to Whetzel, the lilies are attacked at the time they are coming through the soil or shortly thereafter. However, when weather conditions are favorable they may become infected later in the season as well. The fungus, present in the soil, forms spores on

the ground and these are splashed by falling rain into the crowns of the plants. Here a typical rot occurs which may destroy the entire stalk down to the bulb. In other cases, only the growing tip of the plant may be affected leaving a lower rosette of leaves. Affected plants may or may not give rise to weak secondary shoots and any increase in bulb size is inhibited. Whetzel also mentions cases in which attacks just before flowering have occurred, in these instances the tips of the flower stalks alone being killed.

Conidia are formed in great quantity on the leaf surfaces of diseased plants during rainy weather (Ogilvie:17) and secondary infections result following the dissemination of these spores by means of wind and splashing raindrops. The spores may also be carried to nearby healthy plants in the drainage water.

In order to control stump rot, affected plants together with the surrounding soil, should be removed at once. Ditches or drains to carry off the surface water during periods of heavy rainfall will aid in preventing secondary infections. In cases of serious infection, bulbs should not be planted on the same piece of ground the following season. Ogilvie (17) warns against getting soil into the crowns of the plants during the process of weeding or cultivation. New infections have been known to start in this manner.

Excellent control of the disease can be obtained by spraying the lilies with Bordeaux mixture or dusting with copper-lime dust. The fungicides should be applied as soon as the plants appear above ground and the number of applications will of necessity be governed by the amount of rainfall. It is essential to keep the new growth covered with a protective coating of the spray or dust. (For best method of applying copper-lime dust see under control of Botrytis blight above.)

Foot Rot

A disease of lilies known as foot rot has been observed in various states in this country (Drechsler :4 and 5). It was first reported on *L. candidum,* the plants coming from Maryland. Since then it has also been observed on *L. pyrenaicum, L. regale, L. speciosum, L. tenuifolium,* and *L. washingtonianum.* The writer has not observed this disease on lilies in the particular regions he has visited.

The above ground parts of affected plants suddenly topple over. This is the first visible symptom of the disease, and once the plants have fallen, they soon wither and die. Closer examination reveals that the trouble is located in the stem below the soil. Affected stems are shrunken to a part of their normal diameter beginning abruptly at the ground line and extending downward.

Drechsler (4) states that this disease is caused by the fungus *Phytophthora cactorum* (Lebert and Cohn) Schr. It will be noted that the stump rot disease is caused by a fungus belonging to the same genus. Whether the two belong to the same species is not known at the present time.

Due to marked differences in the symptoms exhibited by lilies affected with stump rot and foot rot, Drechsler believes that the two diseases are distinct. The life history of this disease as well as its control has not been worked out as yet. It is very likely, however, that in cases of severe infection, crop rotation should be practiced in order to avoid future trouble. Where only a few plants are affected, they should be immediately removed together with the surrounding soil.

Non-infectious Chloroses

Two types of chlorosis apparently due to psysiological causes

have been observed on lilies. The first of these has been reported from Bermuda in connection with the culture of *L. Harrisii.* Ogilvie (15, 16, 17) in various reports has described the symptoms. They have also been observed by the writer while in Bermuda. In a single instance chlorosis of this type has been noted in a planting of *L. pyrenaicum* on Long Island. In extreme cases, affected lilies are bright yellow, severely stunted and have poor root systems. Whether the poor roots constitute the cause or are a result of the chlorosis is not known. This chlorosis may appear in patches scattered over the field. It usually appears early in the season and often follows periods of heavy rainfall. If the chlorosis is not too marked, affected plants gradually turn green during the latter part of February (Ogilvie:16). In severe cases, dying of the leaf tips may occur and in all cases the lack of chlorophyll results in bulbs smaller in size than those produced by the healthy plant.

This type of chlorosis differs in symptoms from the virus disease, yellow flat, in its bright yellow color as well as in its lack of leaf curling and distortion. It differs from the mosaic disease on the basis of the bright yellow coloration and also the fact that the chlorosis is uniform and does not occur in mottled areas on the leaves.

Ogilvie (17) states that applications of ferrous sulphate, manganese sulphate, magnesium sulphate and various fertilizers have failed to correct the condition. However, bulbs from plants showing a marked degree of the chlorosis have produced healthy plants the following season when grown in a different location. Ogilvie suggests that the chlorosis is induced by certain irregular soil conditions.

The second type of chlorosis has been observed by the writer on *L. speciosum* and its varieties, chiefly in connection with the forc-

FIG. 11
Chlorosis caused by lack of iron in *Lilium speciosum rubrum*. Normal leaf in center.

ing of these plants under glass. In some greenhouses, as many as 50 per cent of the plants may be affected. The chlorosis has been observed more frequently on pot-grown plants than on those grown in benches. In rare cases it has been observed in the field. Affected plants exhibit leaves which are yellow except for the veins which retain their normal green color (fig. 11). Such plants may be slightly stunted and produce fewer flowers. Chlorosis of this type

need not be confused with that caused by the mosaic disease. The general symptoms are strikingly different.

On the assumption that this chlorosis might be in the nature of a virus disease, several attempts were made to transmit it to healthy plants. The results were entirely negative. Due to the fact that the symptoms were similar to those caused by a deficiency of iron in connection with the growing of roses, azaleas and other plants, it was thought that a lack of available iron might be the causal factor in this chlorosis of the lilies. In some preliminary work, results have been obtained which indicate that such may be the case. Pot-grown plants of *L. speciosum rubrum* affected with chlorosis of the above type were treated in various ways with ferrous sulphate. Manganese sulphate was also used on others. Five plants were sprayed with a 0.5 per cent solution of ferrous sulphate and five others were treated by applying one gram of the powdered chemical on the surface of the soil in each pot. This was then washed in with water. The same procedure was followed in using the manganese sulphate. Ten untreated plants were left to serve as checks. In two weeks certain of the iron treated plants began to regain their normal green coloration. At the end of one month, four of the plants having iron on the soil and three of those which had been sprayed had fully recovered. The rest of the plants which had received iron, all of those treated with manganese sulphate and the untreated checks continued chlorotic. This was the only experiment conducted in this connection and further work needs to be done. It has been noted, in certain cases, where varieties of *L. speciosum* in a chlorotic state were growing in benches, that the plants completely recovered their normal color prior to flowering. Although the cause for this remains obscure, it is possible that a change in the hydrogen ion concentration of the soil rendered the iron available once more.

One other case has been reported in which iron apparently cor-

rected a chlorotic condition in lilies. Helen M. Fox (6) mentions an instance where a few plants of *L. auratum* growing in her garden suddenly became chlorotic. The plants recovered soon after she had applied a tablespoonful of ferrous sulphate around the base of each plant.

Brown-tip

A condition known as brown-tip has sometimes been brought to the writer's attention by florists engaged in forcing lily bulbs. Affected plants exhibit a browning and dying of the leaf tips, thus rendering them unsightly. Usually the leaves are not affected for distances greater than from one-quarter to one-half an inch from their apices.

The cause of this condition still remains obscure. No organism was found associated with the trouble. The only observation which might throw any light on the nature of the disease is what appears to be a correlation between the presence of brown-tip and exceedingly wet soils. In the few instances where this trouble has been observed, the lilies were being forced at a rapid rate and the growers were watering the plants rather heavily.

While brown-tip is of slight importance, relatively speaking, in some cases lilies affected in this manner have brought lower prices. Further work is necessary in connection with this trouble.

Other Diseases Reported in the Literature

Aside from the diseases already discussed, there are several others which have been reported as occurring on lilies in the United States. With practically all of them, however, the only available informa-

tion consists of a brief note concerning the pathogene isolated from the diseased material and, in some instances, a short description of the symptoms. In all cases, the pathogenicity of the organism held to be the cause of the disease has not been proved.

The "black scale" disease has been seen now and then on bulbs of *L. Harrisii* coming from Bermuda. The cause of this disease was stated at one time to be due to a fungus belonging to the genus Volutella. Affected bulbs exhibit characteristic black "pocks" on the scales. Late in the season, the Volutella is often found on the dead stems and leaves of lilies. Ogilvie (18) holds that the black scale disease is a physiological condition due to asphyxiation which takes place in heavy or water-logged soils. Affected bulbs invariably produce healthy plants the following season when grown under proper conditions. Accordingly, Ogilvie concludes that the species of Volutella sometimes found associated with this condition is secondary in nature.

Wingard (27) has reported a disease of *L. auratum* from Roanoke, Virginia. Affected plants are severely injured, the flower buds being destroyed when they are in the young state. This disease is stated to be caused by a fungus belonging to the genus Sporotrichum.

Charles and Martin (2) have made brief mention of several diseases of lilies. A species of the fungus Fusarium has been isolated from various lilies sent to Washington from Virginia, Ohio, and the District of Columbia. Another fungus belonging to the genus Cladosporium has been isolated from diseased material sent from Alabama, Ohio, District of Columbia, and Virginia. A fungus, Kabatiella sp., has also been stated by Charles and Martin to be the cause of a disease of *L. auratum*. Affected plants have scorched leaves and buds. In a later publication, Martin (12) reports its

isolation from still other lilies and identifies the fungus as *Kabatiella microsticta Bubak*. The writer has isolated this fungus from certain lilies exhibiting varying symptoms of disease. However, all inoculation experiments thus far attempted have given negative results.

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LITERATURE CITED

1. Arthur J. C. Uredinales. North American Flora **7**:754. 1926.
2. Charles, V. K. and Martin, G. H. Some diseases of lilies. Plant Dis ease Reporter **12**:82. 1928.
3. Doolittle, S. P. The mosaic disease of cucurbits. U. S. D. A. Bulletin 879:1-69. 1920.
4. Drechsler, Charles. Foot-rot of Lilium candidum and Lilium pyrenaicum caused by Phytophthora cactorum. Phytopath. **16**:51-53. 1926.
5. ——— ——— Foot-rot due to Phytophthora cactorum in additional species of Lilium. Plant Disease Reporter **13**:8. 1929.
6. Fox, H. M. Auratum lilies restored by iron. Horticulture **6**:432. 1928.
7. Garman, P. A. A study of the bulb mite. Connecticut Agr. Exp. Sta. Bul. **225**:113-132, 1921.
8. Griffiths, D. The Madonna lily. U. S. D. A. Bulletin **1331**:1-18. 1925.
9. ——— ——— A score of easily propagated lilies. U. S. D. A. Circular **23**:1928.
10. ——— ——— The production of lily bulbs. U. S. D. A. Circular **102**:1920.
11. Kean, A. L. The lily disease in Bermuda. Botanical Gazette **15**:8-14. 1890.
12. Martin, G. H. Certain early developmental phases common to many fungi. Phytopath. **19**:1117-1123. 1929.
13. Massee, G. A lily bulb disease. Garden and Forest **10**:414-415. 1897.
14. McDaniel, E. I. The principal bulb pests in Michigan. Michigan Agr. Exp. Sta. Spec. Bul. **173**:1-23. 1928.

15. Ogilvie, L. Report of the plant pathologist. Annual Report, Bermuda Department of Agriculture **1924**:32-43. 1925.

16. ——— ——— Report of the plant pathologist. Annual Report, Bermuda Department of Agriculture **1925**:36-63. 1926.

17. ——— ——— Report of the plant pathologist. Annual Report, Bermuda Department of Agriculture 1926:35-41. 1927.

18. ——— ——— Report of the plant pathologist. Annual Report, Bermuda Department of Agriculture 1927:26-37. 1928.

19. ——— ——— A transmissible virus disease of the Easter lily. Annals of Applied Biology **15**:540-562. 4 pls. 1928.

20. Pinkhof, M. Untersuchungen über die Umfallenkrankheit der Tulpen. Recueil Trav. Bot. Neerlandais. **26**:135-288. 1929.

21. Plant pathological sub-committee of the British Mycological Society. List of common names of British plant diseases. Transactions of the British Mycological Society **14**:140-177. 1929.

22. Stewart, F. C. Two destructive lily diseases. New York (Geneva) Agr. Exp. Sta. Annual Report 1895:520-524. 1896.

23. Stout, A. B. Why we fail with garden lilies. Journal of the New York Botanical Garden **28**:285-296. 1927.

24. Ward, H. Marshall. A lily disease. Annals of Botany **2**:319-376. 1888.

25. Westerdijk, J. and Kingma, F. H. VanBeyma Thoe. Die Botrytis-Krankheiten der Blumenzwiebelgewachse und der Paeonie. Meded. Phytopath. Lab. Willie Commelin Schol. **12**:1-27. 1928.

26. Whetzel, H. H. Report of the plant pathologist. Annual Report, Bermuda Department of Agriculture 1921:30-64. 1922.

27. Wingard, S. A. Blight of Lilium auratum in Virginia. Plant Disease Reporter **12**:35. 1928.

28. Wright, J. The causal parasite of the lily disease. Transactions of the Botanical Society of Edinburg **30**:59-65. 1928.